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EFFECT OF CHANGE OF POSTURE—WITHOUT ACTIVE MUSCULAR EXERTION—ON THE ARTERIAL AND VENOUS PRESSURES *

JOSEPH H. BARACH, M.D., AND W. L. MARKS, M.D.
PITTSBURGH

In this consideration we present the results of our investigations on the effects produced by change of posture, when this change is brought about without effort on the part of the subject. It is, of course, understood that in the standing posture there is exerted a constant muscular effort, while in the horizontal posture this element is eliminated.

METHODS

Our subjects were placed on a table with a movable top. This top was set and balanced so that when the subject was once placed in position, he had no further occasion for voluntary muscular effort. After stepping onto the foot-board of the table, which was about 6 inches above the floor, the arm-pieces of the blood-pressure instruments were attached. The instrument for arterial pressure was of the usual type, mercury, column, cuff 10 cm. wide. The apparatus for measuring the venous pressure was that of the type constructed by Hooker and Eyster, which is a modification of the one by Von Recklinghausen. The cuff of the arterial pressure apparatus was applied to the right arm at the heart level; the venous measuring attachment, to the left arm whenever possible, at the level of the auricle. The arterial pressure readings, maximum and minimum by the auscultatory method, were made one every minute, beginning on the minute, for five consecutive minutes. After the fifth reading, the venous pressure was estimated. The venous pressure reading finished, the subject was instructed to lean back in a completely passive way, on the table board. He was then tilted to the horizontal posture, and the table top was fastened down with a chain. In most instances it would not have been necessary to fasten the board on account of the balancing toward the upper half of the table. Five consecutive readings of the maximum and minimum pressures were made in this posture, and about half a minute after the last arterial reading the venous pressure was estimated. The table was gradually retitled to the erect posture when five arterial readings and one venous estimation were again made.

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* From the Department of Student Health, Carnegie Institute of Technology.

We presumed that five minutes was a sufficient length of time for the circulation to orient itself in response to the effects of this change of posture, and by eliminating as much as possible, the active muscular effort, we expected results that would be of easier interpretation than when the subject exerts himself in changing his postures.

Material.—The forty-eight subjects of these experiments were students at the Carnegie Institute of Technology; their ages varied between 15 and 30 years. About one-third of these were members of the various athletic teams. Their state of health, their muscular development, the condition of their hearts and their strength tests all enter into this consideration and will be, respectively, considered as influential factors in the behavior of the circulation as it responds to changes in posture.

Arterial Pressures.—The height of the maximum arterial pressures in this series was at the usual level. A curve based on the ages of the subjects would show a gradual increase with the advance of years.

In comparing the regularity of the maximum and minimum pressures we find that the minimum pressure level is more constant—is subject to less variation than the maximum.

It is interesting to note in the individual cases how much fluctuation in the blood-pressure actually takes place each minute under psychic influences. We have eliminated almost every other element in these experiments except this one, which is largely a matter of personal equation. The error due to this is inherent in all work, on the healthy and diseased, on the strong and the weak. So far as the reliability of the total results is concerned, we believe this to be a negligible factor, particularly since we carried the experiments over a five-minute period. The illustrations show this constant oscillation of the arterial pressures.

Venous Pressure.—The venous pressure readings were taken whenever possible on the arm at the level of the subcostal angle, i. e., at the level of the right auricle. Such were the only cases included in our series on which we base our figures of what constitutes an average normal venous pressure.

Our findings in those cases in which we had to make our readings below or above the level of the auricle did not always show a constant relative difference comparable to the distance above or below the mark. In that respect our observations do not bear out those of other investigators.

In our observations on the effect of change of posture on the venous pressure, all our readings are included; since the absolute height of the venous pressure did not enter into the consideration.

Pulse Pressure.—With the advent of the auscultatory method for estimating the maximum and minimum arterial pressures, we were more

certain of our readings in this work than with the graphic method as interpreted by the Erlanger instrument in our former work. The auscultatory method has made the investigation of the pulse pressure accessible for clinical study as well as physiological research and we may hope for valuable information as the evidences accumulate.

ARTERIAL PRESSURES OF THIS SERIES

The height of the maximum pressures ranged between 95 and 140. The minimum pressures between 65 and 92 mm. As previously noted, the greater variation occurs in the maximum pressure, and both maximum and minimum blood-pressure rise with the advance of years (Fig. 1).

In twenty-two of these cases we have the strength test for comparison and study. The test consists of measuring according to the inter-collegiate standard.

In those whose strength total ranged between 704 and 541 kilo, the average maximum pressure in the erect posture was 124.26, the average minimum pressure was 79.35, the pulse pressure 44.91, while in those

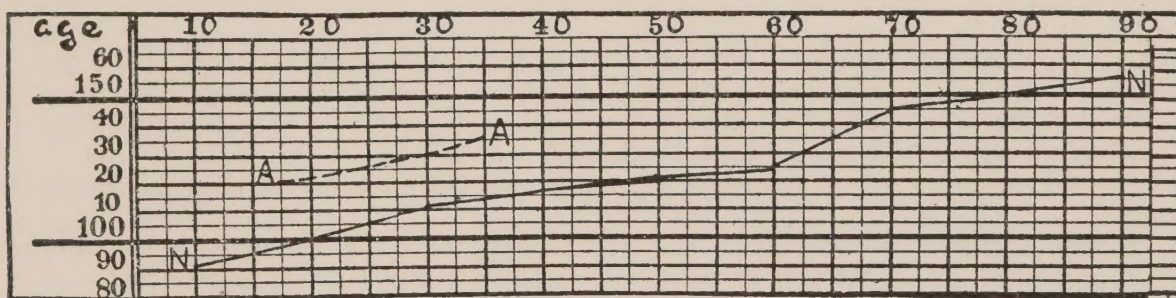


Fig. 1.—Chart showing averages of blood-pressure at different age periods. The line A-A indicates a higher than average blood-pressure in trained athletes.

whose strength tests varied between 505.4 and 355.9 kilo, the average maximum pressure was 120.57, average minimum pressure 74.61 and average pulse pressure was 45.96.

These figures will tend to show that the stronger individuals have higher blood-pressures. This is not entirely true, for the circulation of some of our very best athletes, who are actually human towers of strength and endurance, goes along easily and quietly with a low blood-pressure. Such a one is in fact the best type of athlete. But in a series of athletes we meet with many who have trained up to a point of efficiency, and in that training have developed a compensatory hypertrophy. It is these who have higher than average blood-pressures, and these occur frequently enough to bring up the average. (See Line A—A, Fig. 1.)

Effect of Change of Postures on Arterial Pressures.—The blood-pressure readings, as previously stated, were taken on the minute for five consecutive minutes, first in the erect, then in the horizontal, then again in the erect postures. In studying the effect of change of posture on the

behavior of the arterial pressures, we thought it advisable to extend the readings over a period of five minutes. The pressure readings over these five minutes were averaged and Table 1 shows the results of the change of posture.

The conclusions to be drawn from these observations are: When the element of active muscular exertion has been eliminated, the manner in which the circulatory system responds to the effect of bodily posture, under the stated conditions, is as follows: In changing from the erect to horizontal the maximum pressure will usually be increased, the minimum pressure will almost always be diminished. When the erect posture is resumed, the maximum pressure will almost invariably fall and the minimum almost invariably rise. In the falling of the maximum pressure, when the erect posture is resumed, it will nearly always fall considerably below the previous height of the first reading, while the minimum pressure may be higher or lower than the first reading, with almost equal frequency (Table 1).

TABLE 1.—EFFECT OF CHANGE OF POSTURE ON MAXIMUM AND MINIMUM PRESSURE.

Maximum Pressure			Than	Minimum Pressure			Than
Erect.	Horizontal.	Erect.	First.	Erect.	Horizontal.	Erect.	First.
×	28+	7+	8+	×	4+	43+	25+
	20—	40—	38—		44—	4—	21—

First column: × = height of maximum pressure in erect.

Second column: + = increase of maximum pressure when changed to horizontal.

Second column: — = fall of maximum pressure when changed to horizontal.

Third column: — = fall of maximum pressure when changed to erect.

Third column: + = rise of maximum pressure when changed to erect.

Fourth column: — = the height of maximum pressure was lower when the erect posture was resumed, than the first readings in the erect.

Fourth column: + = height of maximum pressure greater than first.

Columns 5, 6, 7, 8 read in same way as 1, 2, 3, 4.

PULSE PRESSURES

The pulse pressures in this series, in the erect posture ranged between 15 and 72 minimum Hg, the average for the series being 36.46. It was greater in the cases in which the maximum pressure was higher.

Arranged according to age of the subjects, the pulse pressure in the erect posture in those between 16 and 21 years was 37.1 mm., while those between 21 and 30 years was 40.61 mm.

Effect of Change of Posture on Pulse Pressure.—Change of posture from the erect to horizontal caused an increase in forty and a fall in seven. From the horizontal to erect caused a decrease in forty-one and an increase in four. In the fall from the horizontal to erect, the pulse pressure fell lower than it was at the first reading in the erect, in thirty-four cases. It remained higher than the first reading in eleven cases. The pulse pressure seems to vary in the same direction as the maximum pressure.

In the Strongest Half of the Series.—On change from the erect to the horizontal, the maximum pressure was increased in seven and diminished in four. From the horizontal back to the erect, it was diminished in nine and increased in two.

In this fall the maximum pressure reaches a lower level than it was at the first reading in the erect in ten cases out of eleven.

The minimum pressure, in this series, from the erect to horizontal, fell in nine and rose in two. From horizontal to erect, it rose in ten and fell in one. This rise was to a higher level than the first reading in six

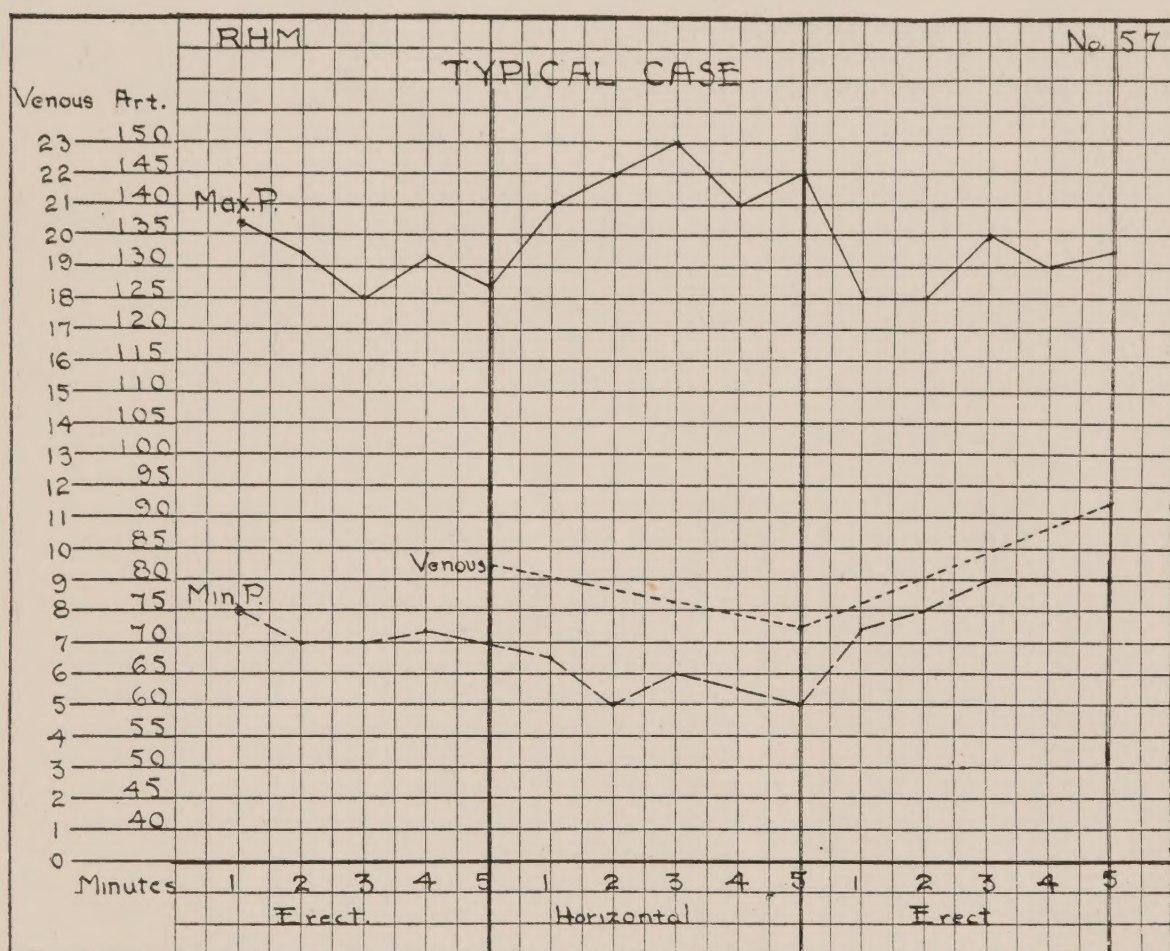


Fig. 2.—Chart showing maximum and minimum pulse-pressure in the erect and horizontal positions in a typical case.

cases and not so high as the first in five cases. The pulse pressure from erect to horizontal increased in nine, and diminished in two. From horizontal to erect, diminished in nine and increased in two. This fall was lower than the first reading in six cases.

In the Weaker Half.—From erect to horizontal, the maximum rose in six and fell in four. From horizontal to erect, caused a fall in eight and a rise in two. This fall was lower than the first reading in the erect in eight and higher in two.

The minimum pressure on change from erect to horizontal fell in nine and rose in one. From horizontal back to the erect again, caused a

rise in all ten. In half of this ten a higher level was reached than the readings in the first erect posture; in the other half it was lower.

In Poor Muscular Cases.—Change from erect to horizontal caused a fall in seven and a rise in six. From horizontal to erect, a fall in nine and a rise in three. In this fall eight out of eleven remained lower than the first readings in the erect posture. The minimum pressure from the erect to horizontal increased in eleven and fell in one. From horizontal back to the erect, increased in six and fell in five.

In Heart Cases.—In this series of heart cases, we make no attempt to classify the lesions. Rather do we include those cases in which the state of the heart is frankly open to the criticism of probable cardiac inefficiency. Two cases showed irregularity, one aortic systolic murmur,

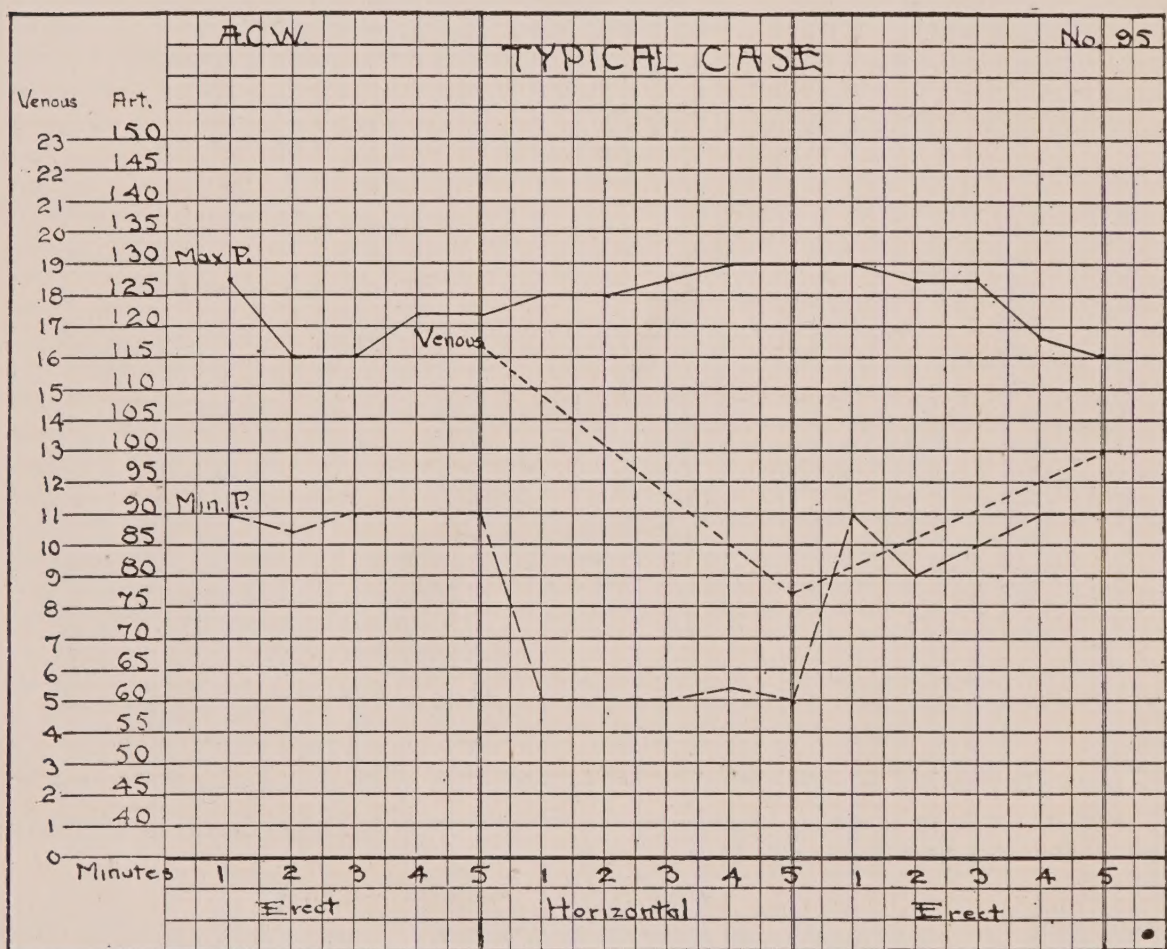


Fig. 3.—Chart showing maximum and minimum pulse-pressure in the erect and horizontal positions in another typical case.

one case Broadbent's contraction from an old pericarditis, two mitral systolic murmur cases, and two cases showed very prominent apex impact with weakness of cardiac sounds. Changing from the erect to the horizontal caused in the maximum pressure an increase in five and a fall in four. From the horizontal back to the erect, a fall in six and an increase in two. This fall was to a lower level in six out of seven cases.

The minimum pressure after change from erect to horizontal, fell in eight and rose in one. From horizontal to erect, rose in seven and fell in one. This rise was to a higher level in five out of eight cases.

VENOUS PRESSURES

To determine first what is the height of the venous pressure in the normal, we picked out of our series of observations twenty-six cases in which we could measure the venous pressure at the level of the auricle.

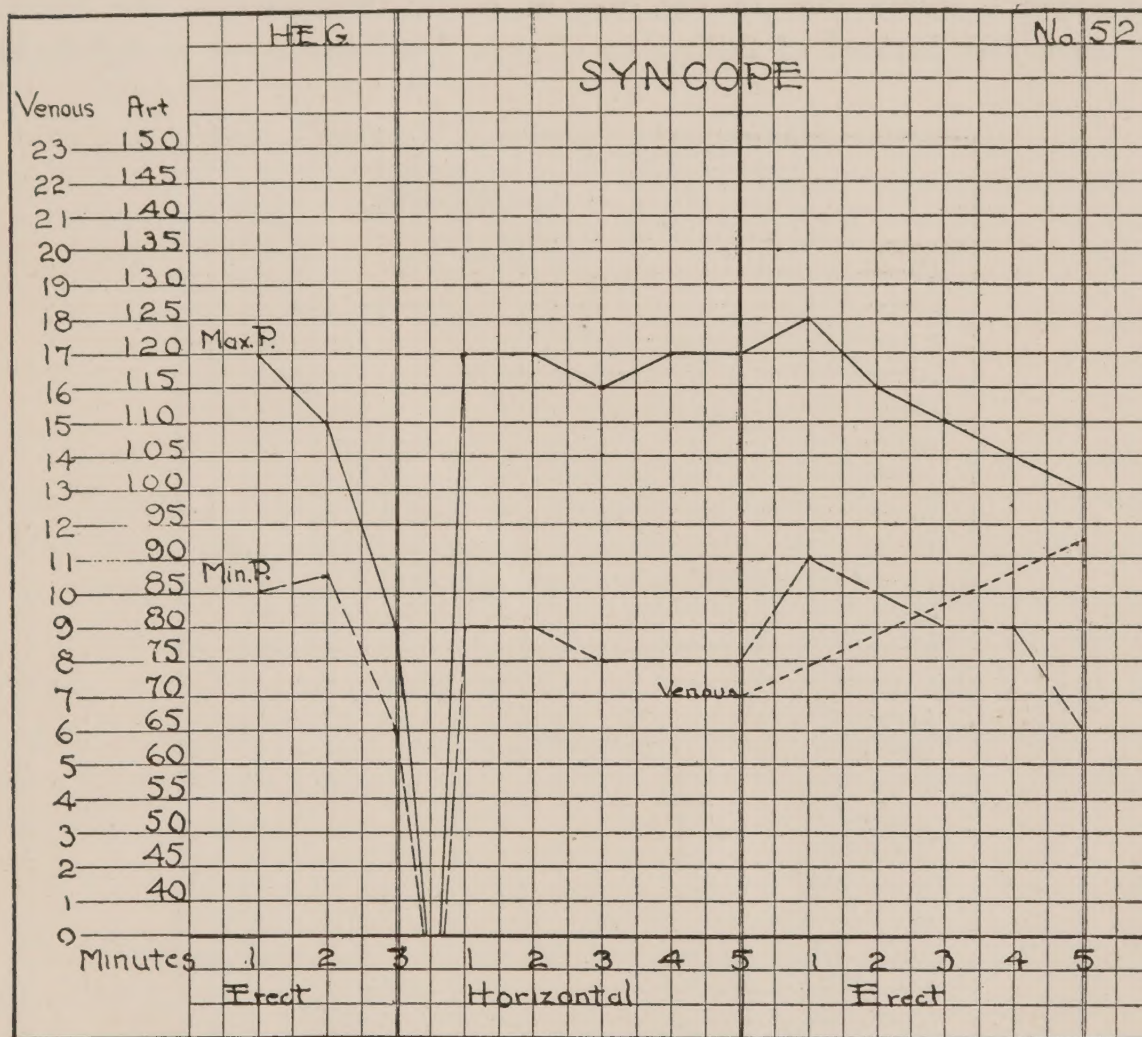


Fig. 4.—Chart showing syncope during the experiment with rapid rise in pulse-pressure on placing the patient in a horizontal position.

In the erect posture the height varied between 8 and 18 cm. water. In the horizontal between 3.5 and 11 cm. The average pressure between the ages of 16 and 20 years was 9.59 cm. in the erect. Between 21 and 26 years 11.2 cm.

Change of posture in all the cases from the erect to horizontal caused a decrease in twenty-four and an increase in two. From horizontal to erect an increase in twenty-five and a decrease in one, and this increased pressure was higher than the first erect posture in twelve. It was lower in eight and equal in five.

RELATIONS BETWEEN THE PULSE PRESSURE AND VENOUS PRESSURE

In table form we arranged the cases according to the height of the pulse pressure average for five minutes. We find that the added venous pressures in the first half, which includes those of the higher pulse pressure, is 127 cm. water, while that of the lower pulse pressures is 123 cm. Showing that in this series the tendency is to greater pulse pressures and greater venous pressures occurring simultaneously.

RELATIONS BETWEEN "HEART CASES" AND VENOUS PRESSURE

Table 2 shows that in the case of aortic insufficiency, the venous pressure rose instead of falling on change from the erect to horizontal

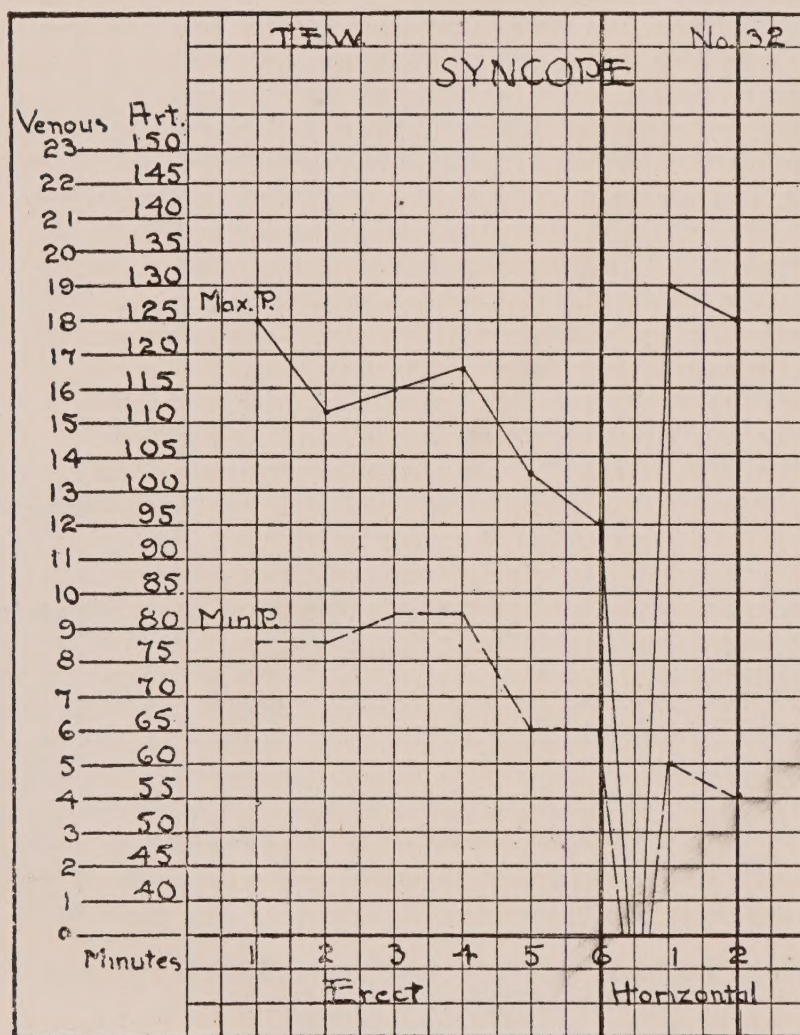


Fig. 5.—Chart showing rapid fall in pulse-pressure during the experiment, with syncope in six minutes. Rapid rise on placing the patient in a horizontal position.

posture. The other cases, irrespective of the lesions, responded as does the normal circulation.

SYNCOPE

In a number of these cases syncope occurred during the examination. The two charts (Charts 4 and 5) show the behavior of the arterial and venous pressures.

In one case (Chart 4) the maximum pressure fell in three minutes, from 120 down to 80; the minimum from 85 to 65, then the pulse at the brachial became inaudible, and the subject soon relaxed to falling. We tilted the table to the horizontal posture and within two minutes got the first reading at which the maximum pressure had reached its former height, but the minimum pressure did not go quite so high as formerly.

After five minutes in the horizontal posture the erect posture was resumed. The maximum pressure responded normally by falling, but the minimum pressure showed a tendency to fall instead of rising as it should. The venous pressure reading from horizontal to erect responded normally.

TABLE 2.—RELATIONS BETWEEN HEART CASES AND VENOUS PRESSURE.

No.		Erect.	Horizontal.	Erect.
18	Aortic insufficiency	×	+	+
92	Hypertrophy—general condition poor.....	×	—	+
36	Mitral insufficiency	×	—	+
54	Broadbent's contraction	×	—	+
35	Irregular heart	×	—	+
90	Hypertrophy—general condition poor.....	×	—	+

The second case (Chart 5) showed a steady falling of pressure with each minute reading, and from the restlessness of the subject we suspected what was going to happen; therefore, we carried on our observations in the first erect posture for six minutes, at which time the sounds at the brachial became inaudible, and the subject a little later, relaxed to falling. After being placed in the horizontal posture, the maximum pressure rose higher than at the first reading in the erect, and the minimum pressure rose, but as in the other case, to not so high a level as formerly. In this case we did not get the venous readings.

SUMMARY

1. When the element of muscular effort has been eliminated, change of bodily posture from the erect to the horizontal will cause an increase in the maximum pressure, a decrease in the minimum pressure and an increase in the pulse pressure.

2. After five minutes in the horizontal posture when the subject is retitled to the erect posture, the maximum pressure will diminish, the minimum pressure increase and the pulse pressure diminish. It will be noted that in both instances the pulse pressure follows the same trend as the maximum pressure.

3. Change of posture from the erect to horizontal caused a fall in the venous pressure.

4. Change of posture from the horizontal to erect caused an increase of the venous pressure.

It will be noted that the venous pressure follows the same trend as the minimum pressure.

Nearly all subjects of this series responded in the same way. The most notable exception was in the "Poor Muscular Cases." These cases showed a tendency to a reversal of the pressure curve. From erect to horizontal caused in more than half of the cases a decrease of the maximum pressure and an increase of minimum pressure.

GENERAL SUMMARY

	Erect	Horizontal.	Erect
Maximum	×	+	—
Minimum	×	—	+
Pulse pressure	×	+	—
Venous pressure	×	—	+

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